A SCALABLE ICT-STRUCTURE FOR SMART GRID SOLUTIONS FOR LOCAL ENERGY COMMUNITIES

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ABSTRACT

As local energy communities are emerging they redefine the well-known energy system. A large number of decentralized energy resources must be integrated and controlled. Different aims have to be considered within the control, e.g. the formation of local energy communities but also need to comply with the voltage bandwidth. A scalable holistic approach that can be used for a variety of structures, e.g. smart distribution grids or local energy communities, and function, like operation or optimization, is required.

In this paper a flexible, adaptable system structure for industrial computers is defined as a basic element for this holistic approach. By using standard technologies from computer science different advantages are realized. An application container allows a flexible use and easy Migration of software components. Through the implementation of software functions such as microservices or webservices and not as a monolithic software a higher degree of flexibility is realized. As an example, the use of this basic elements within a hierarchical ICT System is described. This hierarchical approach is specified and tested under the label "Energy Gateway" within the research project Designetz.

INTRODUCTION

The ongoing grid integration of flexible and decentralized generation and load leads to various challenges. Different targets have to be considered within the control, e.g. the formation of local energy communities or comply the voltage bandwidth. [1] [2] As a result, new requirements are placed for the electrical energy grid and its control framework.

The requirements to operate the existing grid or new locally orientated grids with a high reliability increase. In order to realize local energy communities' similar requirements have to be considered. Every structure has the target of achieving a high quality and reliability of supply. Therefore, a system design should be defined that can be used flexible for the different grid structures and required functions.

This paper will focus on the properties and structures needed for grid operation. Market functions and IT-security implementations are not described here, because they will be developed and implemented from research partners within the project Designetz. Within this paper, the expression of basic elements called data nodes is presented. The aim of this elements is to provide a flexible structure to meet requirements for local energy cells, energy communities and traditional distribution grids.

LOCAL ENERGY COMMUNITIES

Within this paper, the application of the developed basic elements within the area of local energy communities (LEC) is considered. Therefore, a short overview which structures are considered under the term local energy communities is presented.

The idea behind the local energy communities is the aggregation of distributed energy resources and storage with the local energy needs from a local user group. [3] That leads to minimum CO^2 emissions and operating costs for the transmission of electrical energy. In particular, LEC want to generate financial, social and environmental benefits. The idea of LEC is often based on microgrid structures. These LEC can either be defined embedded in the existing distribution grid or set up as isolated grid islands. [4]

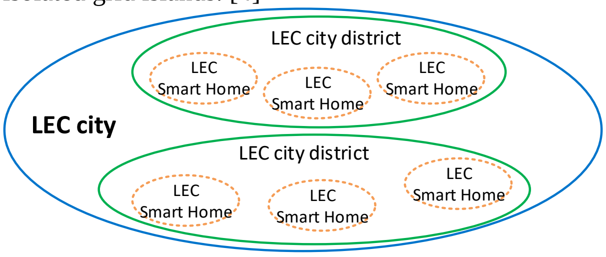

figure 1: formation of differently sized LEC

A larger Smart Building, with its own power generation, storage and corresponding control functions can thus already be defined as LEC. Several of these LEC Smart Buildings can join each other in order to form an overlaying LEC, e.g. a local city district community (see figure 1). By this definition, it is also conceivable that an LEC may contain several other LECs, which may be formed by different structures.

NETWORKINTEGRATION WITH THE ENERGY GATEWAY

The holistic approach of a different number of data nodes and functions is called Energy Gateway. The structure of the Energy Gateway should be selected based on the grid structure and the planned application. However, the architecture of the basic elements remains the same.

Functions and structure within a data node

A data node contains the necessary functions and databases to autonomously control a grid.

Functionality of a data node

No matter in which context the data node is going to be used, some basic functions are needed. These include measured value functions, hence recording, checking, processing and provision. Further pieces of information such as status messages must be processed independently of the specific application. These basic functions are, although not always fully used, available on every data node.
In addition to that, different operating functions, optimization functions or other functions such as local energy trading within an energy community may be included.
An exemplary overview of possible functions is shown in figure 2.

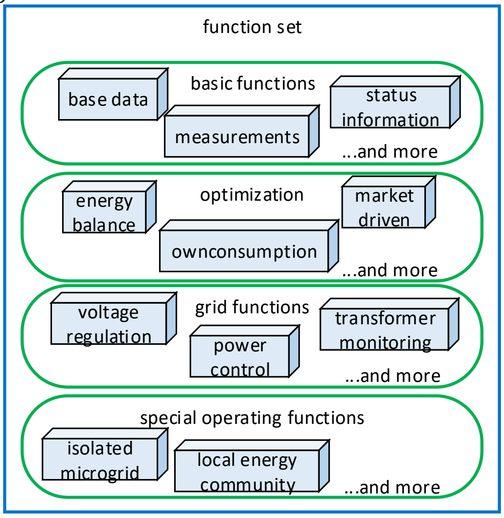

figure 2: possible function set

In accordance to the operating range various combinations of functions are required. The available functions should therefore be as flexible and easy to combine with others as possible. However, unneeded functions should not be included in order to avoid the unnecessary use of any memory or CPU resources. Splitting a monolithic software into several functional fragments, increases the usable synergies of the subsystems emerging. This can be realized through the implementation of services, for example according to the structure of microservices. The microservices include subproblems that are straightforward to solve. The use of functional software components leads to different advantages, which are mentioned in figure 3. [5] [6]

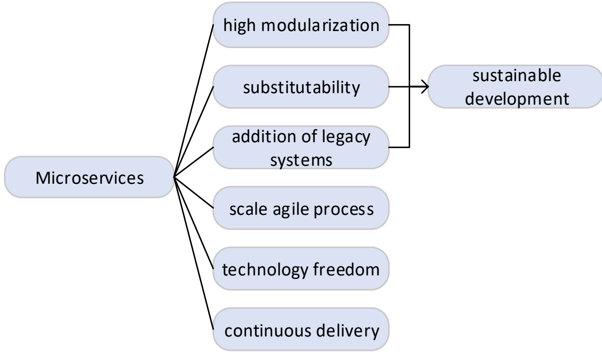

figure 3: advantages of microservices [5]

However, this also increases the amount of communication between the software services, so determining the proper amount of microservices is highly dependent on the application and the allowed operating delay through communication.

Selected system structure within a data node

The system structure is defined independently of the hardware properties. So it is possible to use the structure for smart building application as well as for distribution grid automation. Application containers are used to enable such kind of hardware independence and the operation of functional services.

The application container in combination with the encapsulated software functions leads to many advantages. Since containers of functions ship all their dependencies they can be used stand-alone. Dependencies between software functions and the hosting system are avoided. The developer's productiveness can be increased by using containers, since e.g. the programming can be done in the preferred environment and only on the developer's machine. All dependencies of services are included in the corresponding container, so usually no compatibility issues would arise in the target system. As a result the risks that services might only be running on the developer's machine properly or that a specific host system would be required are eliminated. [5] [7] [8]
However, the subdivision into different containers leads to an increased need for communication within a data node, [9] so the encapsulation should be subject to different rules like separation-of-concerns, low coupling and high cohesion.

Exemplary System Configuration

As a basis on each data node an operating system is installed (see figure 4). In order to structure the functions and to enable prioritization different virtual machines are set up. Each VM is assigned fixed resources, so management functions cannot use resources that are necessary for the process operation. Also, access between the VMs can be prevented, so that web accesses provided in the management area cannot access the process area if properly configured. [10] [11] The VM "security" and "services" named in figure 4 are created by research partners within the Designetz. Within the virtual machines an application container technology is used.

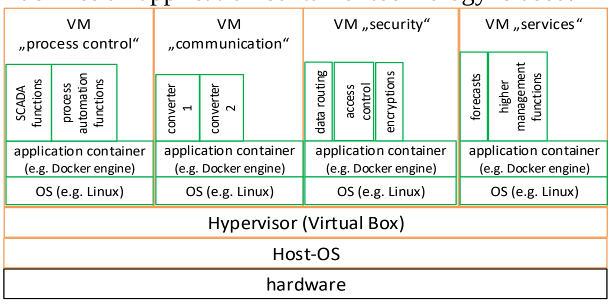

figure 4: system architecture from data node

In order to enable a variety of different functions from different manufacturers and the connection of various devices, standardized communication is used. Within the process area, all used communication standards are translated to the industry standard OPC-UA. [12] All functions and communicated systems are connected to an OPC UA server (see figure 5). Various other functions and communication adapters can be connected to this standard communication.

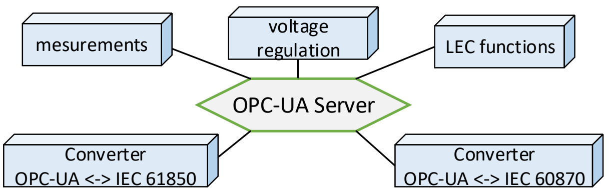

figure 5: communication connection between different functions and systems

Using Data nodes within Designetz

The goal of the research project DESIGNETZ is to create a blueprint of a user-oriented future energy system based on flexibility. Information and communication technologies are used to combine existing and new individual solutions into an efficient overall system. The ICT structure should provide a platform capable of solving existing and new challenges and not cause any limitation in the solution. [13]

The project Designetz is focused on optimized distribution network operation and the use of flexibilities. Within the demonstrators, local energy communities are formed. As a part of the Designetz, a three-level hierarchical energy gateway is going to be tested (see figure 6). The intelligence levels are represented by local, regional and over regional data nodes. The different function blocks of a node are used as containers according to the level and the connected elements. This Energy Gateway is based on a structure consisting of distributed hardware components and a decentralized communication approach. With this approach it is possible to record, process and bundle data at the lowest practicable level. In each level, market and grid-functions can be placed. Depending on the number of required connections, a different number of hierarchy levels can be used. It enables decentralized autonomous functions and is able to handle the data volumes. The connection of higher-level components, such as a central market platform or the SCADA-system of the DSO, is implemented at the highest aggregation level in order to avoid a double interfacing of the same system.

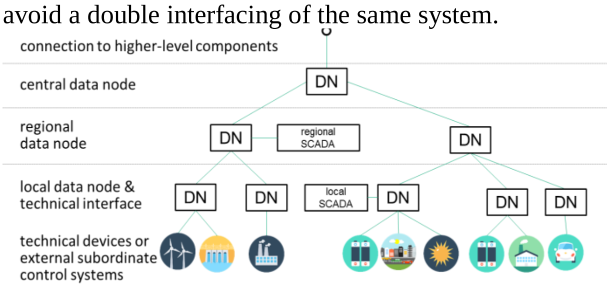

figure 6: hierarchical system

However, other some functions can be realized by the data nodes locally. This makes central operation as possible as the realization of a distributed sub system. The data nodes thus only specify the structure how the different systems and controls are to be integrated and do not limit the scope of functions. The properties of a hardware also do not limit the structure. Should a hardware no longer provide the required resources, the system can easily be migrated to a different hardware.

FURTHER RESEARCH ITEMS

Within the project different workspaces will be considered or provided by research partners.

Communication

The consistent implementation of the hierarchical system provides a decentralized infrastructure. A failed component thus has only a limited influence on the function of the entire system. It is therefore necessary to examine how the communication within the system can be established. Relying on a standard vendor for the routing of the data via a data centre results in a dependency on a component of a third-party operator in the overall system. It should therefore be examined how a decentralized communication network can be used to establish completely decentralized and economic communication.
In particular, it must still be determined which performance with regard to data communication in the selected internal structure is possible. And which transmission times will arise for the different sub systems. In particular for time-critical applications, a defined maximum time delay must be ensured.

Data modelling and function description

Another area of concern is data modelling and description. There are different possibilities for data description. The use of existing standards should be considered for uniform modelling. A standard to be tested is the Common Information Model (CIM). E.g. CIM currently covers exclusively electrical systems. As decentralised energy resources include also other sectors such as e.g. gas a proper model for these is necessary, too. In order to classify the functions easier, they should be fully described. However, also used data and interfaces must be named. One approach is to use the smart grid architecture model (SGAM).

CONCLUSION AND OUTLOOK

In this paper, the structure of data nodes needed for integration of distributed energy resources is presented. This can be used for different applications, like local energy communities. The scope of functions can be put together flexibly and application-oriented choosing from existing and new function blocks. By using virtual machines, resources can be hard-coded, providing a process area with sufficient resource capacity is available. The application containers, on the other hand, ensure better utilization of the resources available, since unnecessary containers are either not loaded at all or shut down. Thus, their resources will be released. Also, the containers allow use of the functions without dependencies on any hardware or any other software components.

If the control functions are implemented functionally separated from each other, they can be flexibly used in future structures. Synergies between the controllers can thus be used optimally. At the example of Designetz it was shown that the arrangement of the data nodes can be chosen freely.

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